

HOT-AIR ENGINE

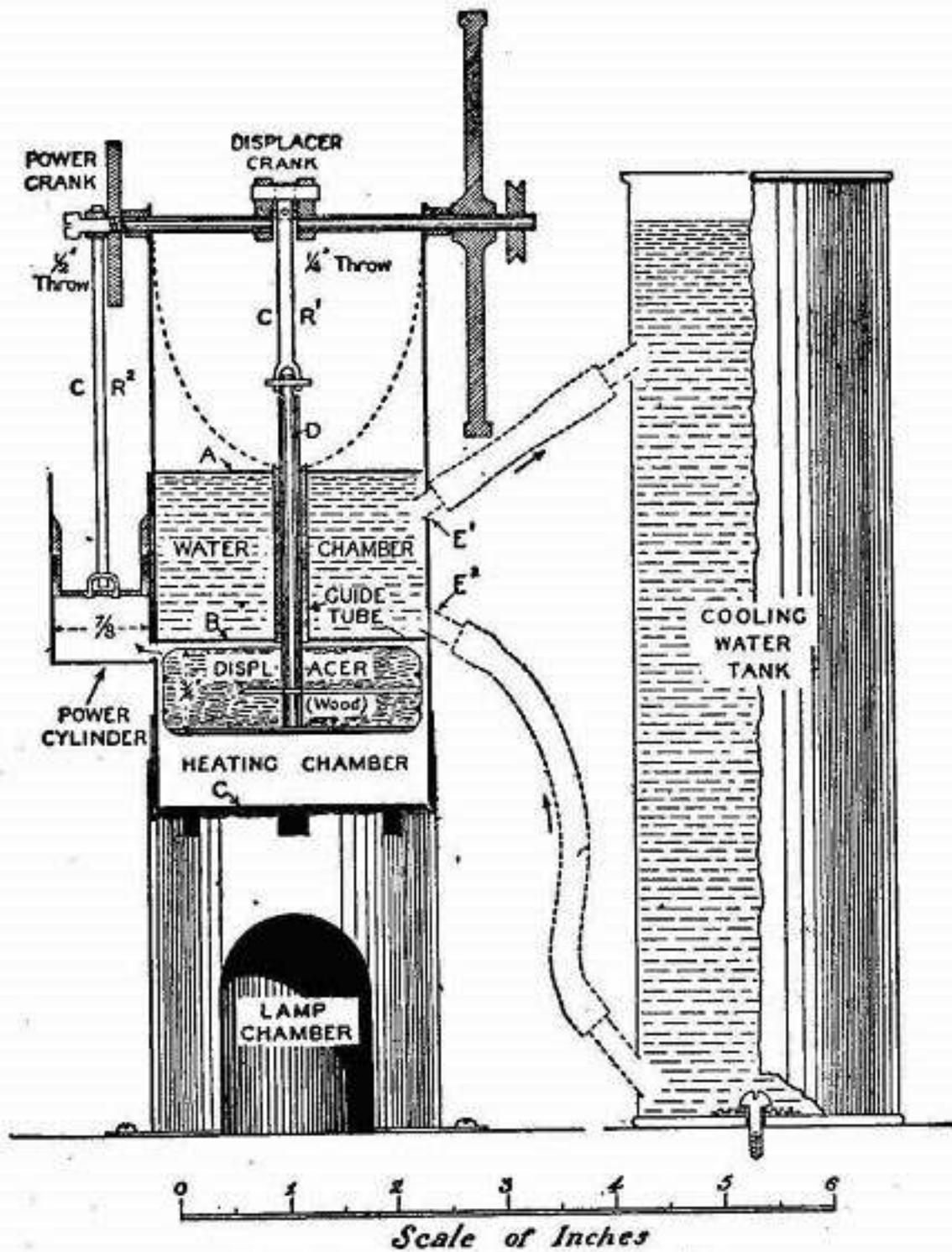


FIG. 97.—Vertical section of hot-air engine.

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The pretty little toy about to be described is interesting as a practical application to power-producing purposes of the force exerted by expanding air. It is easy to make, and, for mere demonstration purposes, has an advantage over a steam-engine of the same size in that it can be set working in less than a minute, and will continue to act as long as a small spirit flame is kept burning beneath it; it cannot explode; and its construction is a simpler matter than the building of a steam-engine.

Principles of the Hot-air Engine

Fig. 97 gives a sectional view of the engine. The place of what would be the boiler in a steam-engine of similar shape is taken by an air chamber immediately above the lamp, and above that is a chamber through which cold water circulates. In what we will call the heating chamber a large piston, known as the *displacer*, is moved up and down by a rod D and a connecting rod CR1. This piston does not touch the sides of the chamber, so that the bulk of the air is pushed past it from one end of the chamber to the other as the piston moves. When the displacer is in the position shown -- at the top of its stroke -- the air is heated by contact with the hot plate C, and expands, forcing up the piston of the power cylinder, seen on the left of the engine. (The power crank and the displacer crank are, it should be mentioned, set at right angles to one another.) During the second half of the power stroke the displacer is moved downwards, causing some of the air to pass round it into contact with the cold plate D. It immediately contracts, and reduces the pressure on the power piston by the time that the piston has finished its stroke. When the power piston has reached the middle of its downward stroke, the displacer is at its lowest position, but is halfway up again when the

power piston is quite down. The air is once again displaced downwards, and the cycle begins anew. The motive power is, therefore, provided by the alternate heating and cooling of the same air.

Construction

The barrel and supports were made out of a single piece of thin brass tubing, 2-7/16 inch internal diameter and 5-5/8 inch long. The heating end was filed up true, the other cut and filed to the shape indicated in Fig. 98 by dotted lines. The marking out was accomplished with the help of a strip of paper exactly as wide as the length of the tube, and as long as the tube's circumference. This strip had a line ruled parallel to one of its longer edges, and 2-1/2 inches from it, and shaded part of Fig. 98 was drawn on an end fold, and all the four folds cut through along this line with a pair of scissors. When opened out, the paper appeared as in Fig. 98.

We now -- to pass into the present tense -- wrap this pattern round the tube and scratch along its edges. The metal is removed from the two hollows by cutting out roughly with a hack saw and finishing up to the lines with a file.

The next things to take in hand are the displacer rod D and the guide tube in which it works. These must make so good a fit that when slightly lubricated they shall prevent the passage of air between them and yet set up very little friction. If you cannot find a piece of steel rod and brass tubing which fit close enough naturally, the only alternative is to rub down a rod, slightly too big to start with, until it will just move freely in the tube. This is a somewhat tedious business, but emery cloth will do it. The rod should be 3-3/8 inches, the tube 2-1/8 inches, long. I used rod 3/16 inch in diameter; but a smaller rod would do equally well.

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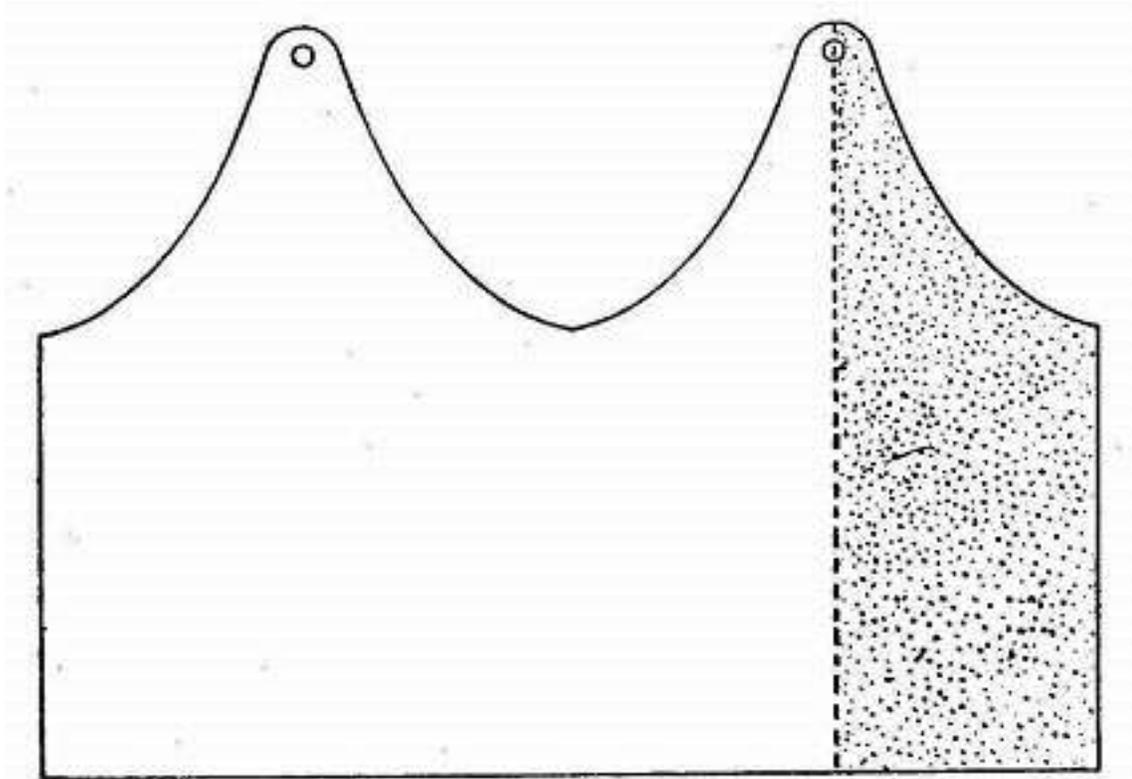


FIG. 98.

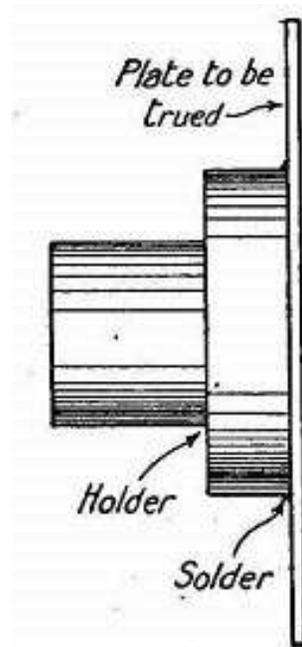


FIG. 99.

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The two plates, A and B, are next prepared by filing or turning down thin brass¹ discs to a tight fit. (*Note.*-- For turning down, the disc should be soldered centrally to a piece of accurately square brass rod, which can be gripped in a chuck. I used a specially-made holder like that shown in Fig. 99 for this purpose.)

When a good fit has been obtained, solder the two discs together so that they coincide exactly, and bore a central hole to fit the guide tube tightly. Before separating the plates make matching marks, so that the same parts may lie in the same direction when they are put in position. This will ensure the guide tube being parallel to the barrel.

The power cylinder is a piece of brass tubing 2 inches long and of 7/8-inch internal diameter. The piston is of 7/8-inch tubing, fitting the cylinder easily, and thick enough to allow a shallow packing recess to be turned in the outside. Brass washers turned or filed to size form the ends of cylinder and piston. The connecting rod CR2 is a piece of strip brass, 3-3/16 inches long, between centres of holes. This had better be cut off a bit long in the first instance, and be fitted to the little stirrup which attaches its lower end to the piston. The drilling of the crank pinhole should be deferred till the cylinder and crank are in position.

Putting in the Water-chamber Discs

Clean the inside of the barrel thoroughly with sandpaper; also discs A and B round the edges and the central holes. Disc A is forced in from the crank end a little further down than it is to be finally, and then driven up from below until at all points its lower side is exactly three inches from the bottom edge of the barrel. Disc B is then forced up 1-1/2 inches from the bottom end. The guide tube - which should have been cleaned -- having

been driven into place, solder is run all round the joints. If the barrel is heated over a spirit lamp, this operation is performed very quickly. ("Tinol" soldering paste is recommended.) Before soldering in B, drill a small hole in the barrel between A and B to allow the air to escape.

Attaching the Cylinder

Scratch a bold line through the centre of one of the crank holes to the bottom of the barrel, to act as guide. Drill a 5/32-inch hole in the barrel on this line just below plate B, and a similar hole in the bottom of the cylinder. (The cylinder end should be put in position temporarily while this is done to prevent distortion.) Flatten down the cylinder slightly on the line of the hole, so that it may lie snugly against the barrel, and clean the outside of the barrel. Lay the cylinder against the barrel with the holes opposite one another, and push a short piece of wood through to exclude solder from the holes and keep the holes in line.

Half a dozen turns of fine wire strained tightly round cylinder and barrel will hold the cylinder in place while soldering is done with a bit or lamp. The end of the cylinder should then be made fast.

The Displacer

This is a circular block of wood -- well dried before turning -- 5/8 inch thick and 3/32 inch less in diameter than the inside of the barrel. The rod hole in it should be bored as truly central as possible. A hole is drilled edgeways through the block and through the rod to take a pin to hold the two together. To prevent it splitting with the heat, make a couple of grooves in the sides to accommodate a few turns of fine copper wire, the twisted ends of which should be beaten down flush with the outside of the block. The bottom of the block is protected by a disc of asbestos card held up to the wood by a disc of tin nailed on.

¹ Thin iron plate has the disadvantage of soon corroding.

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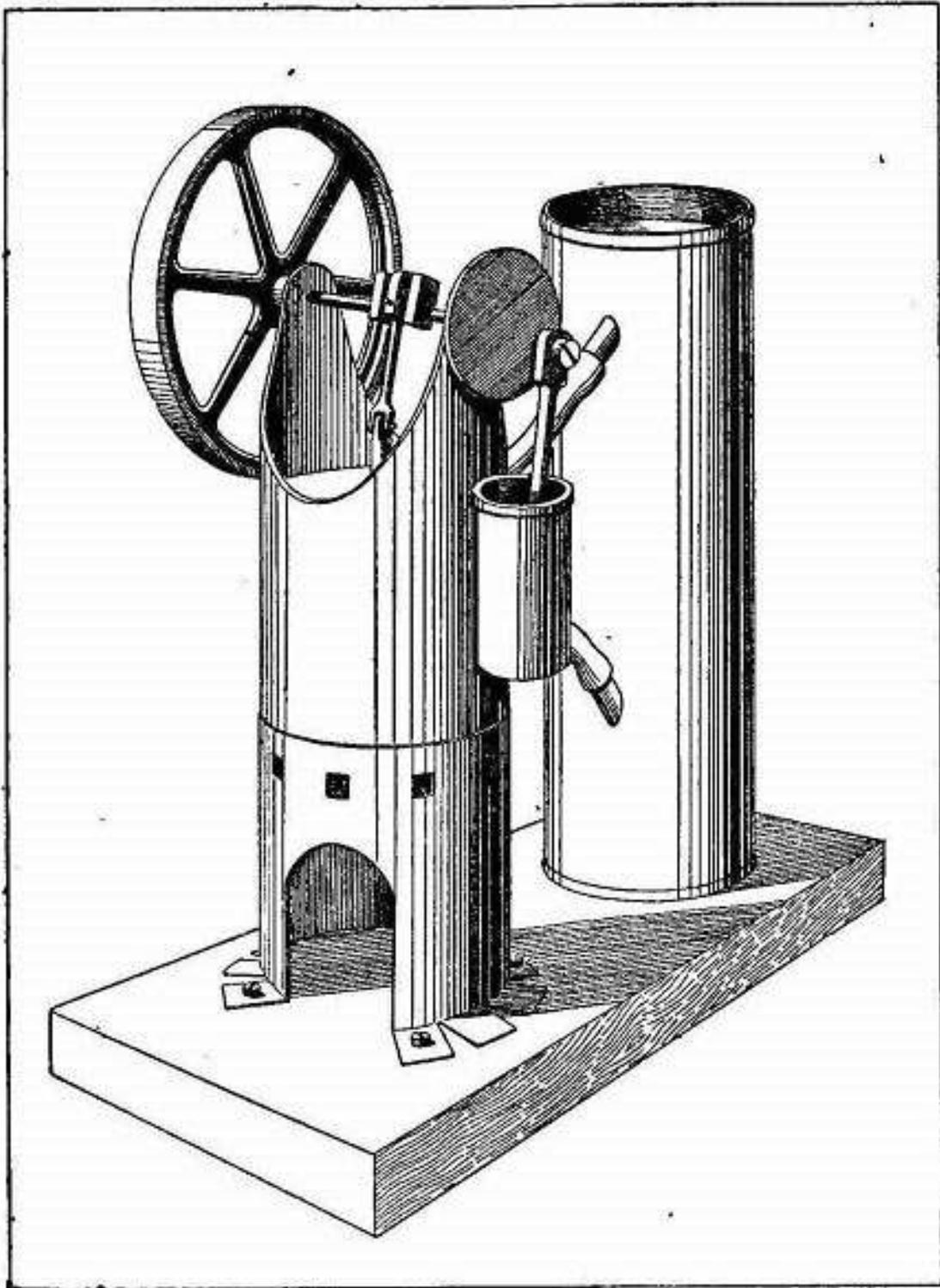


FIG. 100.—Exterior view of hot-air engine.

The Crank Shaft and Crank

The central crank of the crank shaft -- that for the displacer -- has a "throw" of 1/4 inch, as the full travel of the displacer is 1/2 inch. If the bending of a rod to the proper shape is beyond the reader's capacity, he may build up a crank in the manner shown in Fig. 101. Holes for the shaft are bored near the tops of the supports, and the shaft is put in place. After this has been done, smoke the shaft in a candle flame and solder two small bits of tubing, or bored pieces of brass, to the outside of the supports to increase the length of the bearing. The power-crank boss is a 1-1/2-inch brass disc. This crank has a "throw" of 1/2 inch.

Connecting Rods

Put a piece of card 1/16 inch thick in the bottom of the cylinder and push the piston home. Turn the power crank down and mark off the centre of the hole for the crank pin in the connecting rod CR2. Solder a piece of strip brass on each side of the rod at this point; measure again, and drill.

The top of the displacer rod D is now filed flat on two sides and drilled. Slip a ring 1/16 inch thick over the rod and push the rod upwards through the guide tube till the displacer can go no farther. Turn the displacer crank up and measure from the centre of the hole in the rod to the centre of the crank. The top of the connecting rod should be filed to fit the under side of the crank, against which it should be held by a little horseshoe-shaped strap pinned on. (Fig. 102). (Be sure to remove the ring after it has served its purpose.)

The Water Circulation

The water chamber is connected by two rubber tubes with an external tank. In Fig. 97 the cooling water tank is shown, for

illustrative purposes, on the fly-wheel side of the engine, but can be placed more conveniently behind the engine, as it were. Two short nozzles, E1 and E2, of 1/4-inch tube are soldered into the water chamber near the top and bottom for the rubber pipes to be slipped over, and two more on the water tank. For the tank one may select a discarded 1 lb. carbide tin. Cut off the top and solder on a ring of brass wire; make all the joints water-tight with solder, and give the tin a couple of coatings of paint inside and outside.

Closing the Hot-air Chamber

When all the parts except the lamp chamber have been prepared, assemble them to make sure that everything is in order. The lower end of the hot-air chamber has then to be made air-tight. Soldering is obviously useless here, as the heat of the lamp would soon cause the solder to run, and it is impossible to make a brazed joint without unsoldering the joints in the upper parts of the engine. I was a bit puzzled over the problem, and solved it by means of the lower part of an old tooth-powder box stamped out of a single piece of tin. This made a tight fit on the outside of the barrel, and as it was nearly an inch deep, I expected that if it were driven home on the barrel and soldered to it the joint would be too near the water chamber to be affected by the lamp. This has proved to be the case, even when the water is nearly at boiling point. If a very close-fitting box is not procurable, the space between box and barrel must be filled in with a strip of tin cut off to the correct length.

The Lamp Chamber

Cut out a strip of tin 4 inches wide and 1 inch longer than the circumference of the lower end of the hot-air chamber. Scratch a line 1/2 inch from one of the sides, a line 3/4 inch from the other, and a line 1/2 inch from each of the ends.

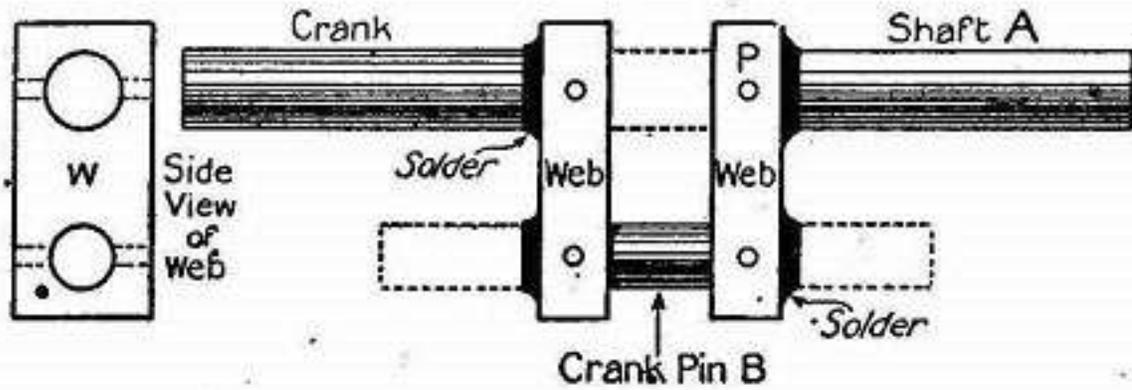


FIG. 101.—Details of built-up crank.

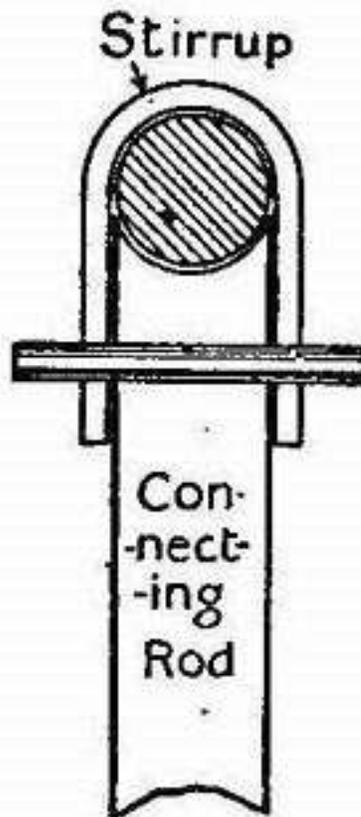


FIG. 102.

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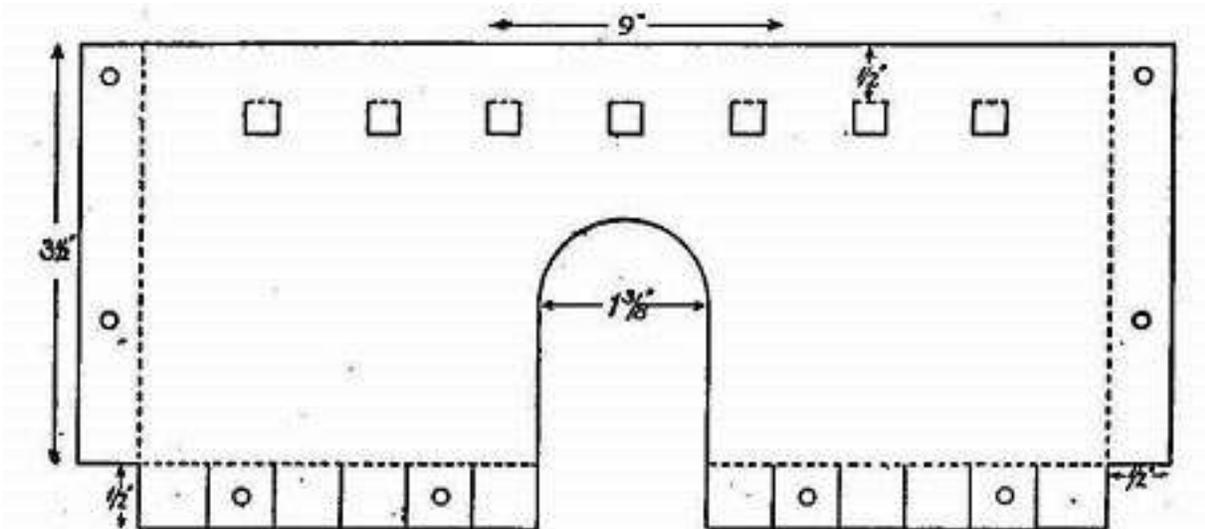


FIG. 103.—Plate for lamp chamber cut out ready for bending.

A lamp hole is cut in the centre, and ventilation holes 1 inch apart, as shown in Fig. 103. If the latter holes are made square or triangular (base uppermost), and the metal is cut with a cold chisel so as to leave the side nearest the edge unsevered, the parts may be turned up to form supports for the barrel.

The slit lower side of the plate is splayed out into a series of "feet," by three or more of which, the chamber is secured to the base.

Bend the plate round the barrel and put the two screws and bolts which hold the ends in place, and tighten them until the barrel is gripped firmly. Screw the engine to its base, fit on the rubber water connections, and fasten down the tank by a screw through the centre of the bottom. The screw should pass through a brass washer, between which and the tank should be interposed a rubber washer to make a water-tight joint.

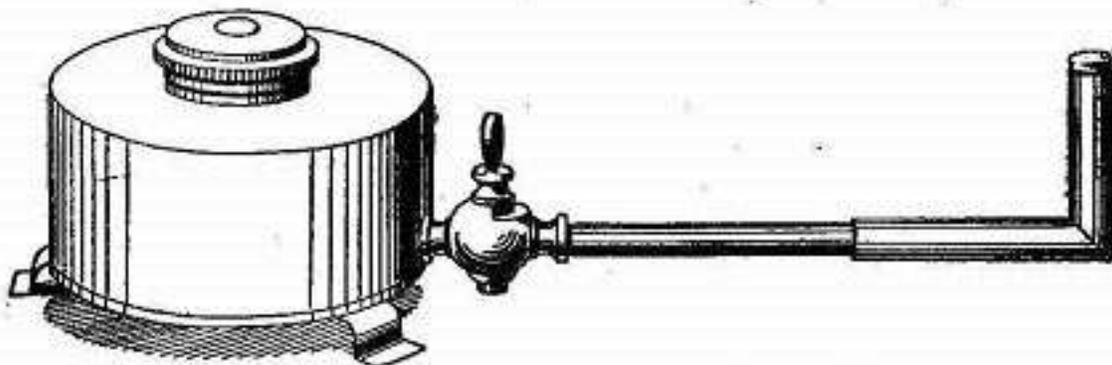


FIG. 104.—Spirit lamp for hot-air engine, with regulating tap.

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The Lamp

The lamp shown in Fig. 104 was made out of a truncated brass elbow, a piece of 5/16-inch brass tube, and a round tin box holding about 1/3- pint of methylated spirit. A tap interposed between the reservoir and burner assists regulation of the flame, and prevents leakage when the lamp is not in use.

Running the Engine

The power and displacer cranks must be set exactly at right angles to one another, and the first be secured by soldering or otherwise to the crank shaft. The fly wheel will revolve in that direction in which the displacer crank is 90 degrees ahead of the other.

The packing of the piston should be

sufficiently tight to prevent leakage of air, but not to cause undue friction. When the packing has settled into place, an occasional drop of oil in the cylinder and guide tube will assist to make the piston and slide air-tight.

The engine begins to work a quarter of a minute or so after the lamp is lit, and increases its speed up to a certain point, say 300 revolutions per minute. When the water becomes very hot it may be changed. The power might be applied, through demultiplying gear, to a small pump drawing water from the bottom of the tank and forcing it through the water chamber and a bent-over stand pipe into the tank again. This will help to keep the water cool, and will add to the interest of the exhibit by showing "work being done."

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